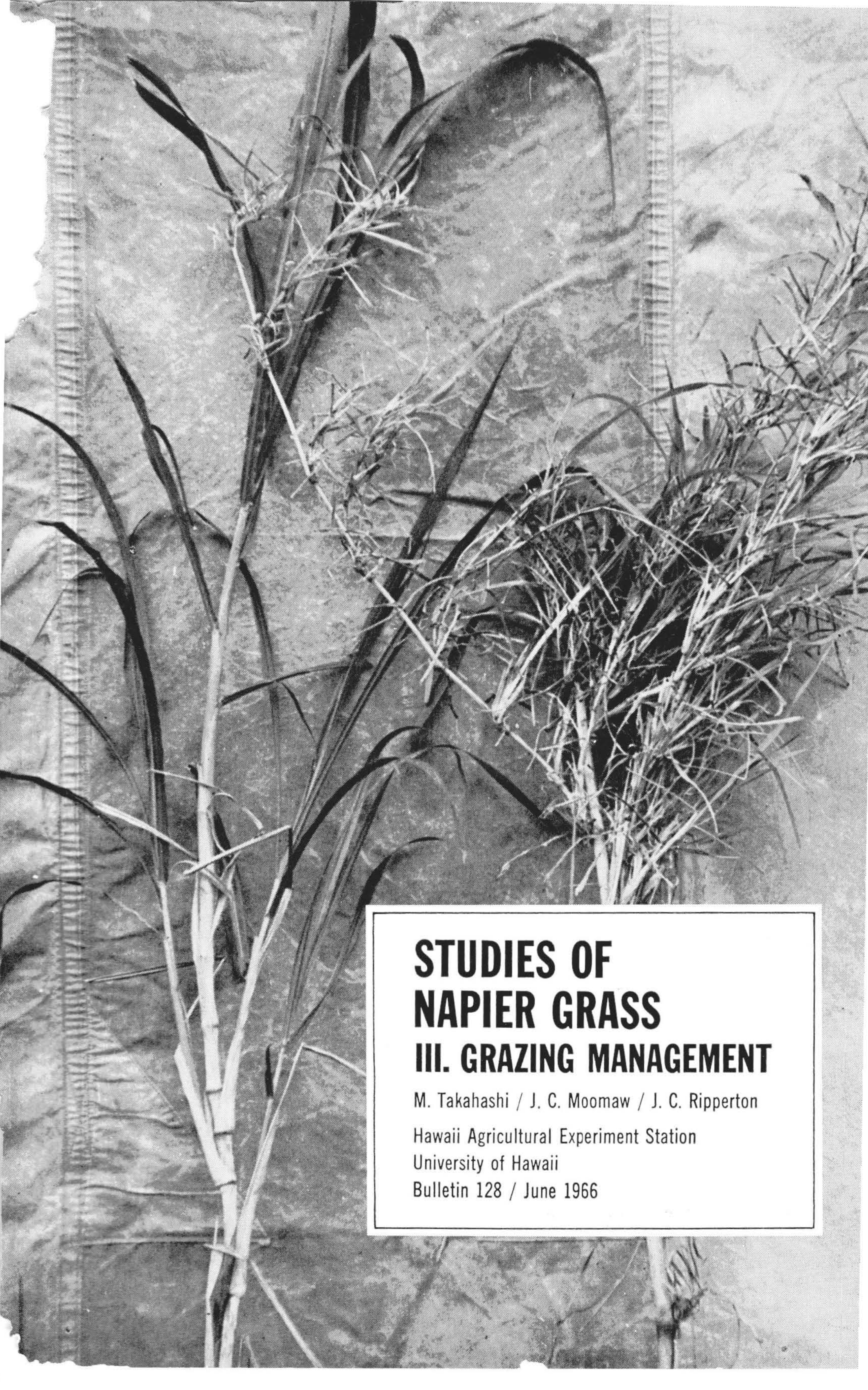

STUDIES OF NAPIER GRASS
III. GRAZING MANAGEMENT

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STUDIES OF NAPIER GRASS: III. GRAZING MANAGEMENT

M. TAKAHASHI, J. C. MOOMAW, AND J. C. RIPPERTON[1]

INTRODUCTION

Napier grass (*Pennisetum purpureum* Schum.) is comparatively a newcomer among the leading forage grasses of the tropics, as its value as a forage crop was only first recognized in 1908, in Rhodesia. Its rise since then, however, has been meteoritic, and within a few decades it has spread to nearly every sector of the tropics. Hawaii was one of the pioneers in acquiring this newly discovered promising grass, having introduced it in 1915 from the United States Department of Agriculture. Its value was recognized by local livestock producers, and within a few years after its introduction it became widely distributed throughout Hawaii. Present acreage estimates indicate that about 1200 acres are grown in the State, of which about 200 acres are grown for soilage, primarily on the islands of Oahu, Maui, and Kauai. Elsewhere in the tropics it is grown extensively but almost exclusively as a soilage crop.

From the standpoint of research on tropical grasses in Hawaii, Napier grass has received more attention than any other forage grass. Interest in this grass for pasturage in Hawaii has subsided considerably since the disastrous outbreak of Napier grass eye-spot disease *(Helminthosporium sacchari)* in 1939, and the subsequent introduction, in 1951, of pangola grass *(Digitaria decumbens),* the acreage of which has expanded phenomenally in the decade since its introduction.

As a soilage grass, Napier grass probably has no peer. Once established and under proper management, it will remain productive almost indefinitely and will produce upwards of 150 tons of green forage per acre per year. Its distinctive features are aggressiveness; long life; drought resistance; freedom from weeds, insects, and diseases (disease-resistant strains); and high production of forage of generally medium quality.

During the early years of its expanded planting in Hawaii, this robust canelike grass was grown almost exclusively as soilage, as elsewhere. Later as it appeared to have potentialities as a pasture grass, trial plantings for pasturage were initiated.

[1] Appreciation is expressed to Kazuo Murakami, Farm Manager, and to the staff of the Haleakala Branch Station for their careful work and cooperation in performing the experimental operations. Emeritus Professor J. C. Ripperton died on February 15, 1960, before he had an opportunity to review this manuscript of the research he had conducted.

The first major planting for pasturage was made at Princeville Plantation, a cattle ranch on the island of Kauai, where some 600 acres were planted for pasturage around 1926. It proved to be an immediate success and other ranches quickly followed suit; but since the use of a large forage grass such as Napier grass, for pasturage, was a new experience and there were no standards to go by, a few of the pastures fared badly through faulty grazing management. In a few instances, stands were decimated almost completely within 2 years after establishment. It soon became evident that this supposedly fool-proof soilage grass would not stand up under faulty grazing management.

In 1939, grazing management studies on Napier grass were initiated in an attempt to shed light on proper grazing management for the maximum production of animal gains without jeopardizing the persistence of pastures. Unfortunately, however, the strain used for the studies turned out to be susceptible to Napier grass eye-spot disease, which made its appearance about the time of establishment, and thus the plantings had to be abandoned and started anew. The grazing management experiment reported in this bulletin was installed in 1941 to replace the ill-fated first trial.

Besides the immediate problem of investigating grazing management of Napier grass, there is the bigger problem of the fundamental aspects of management of rank-growing, tropical pasture grasses; namely, (1) the low rate of utilization, particularly in the rank-growing species with tall, tussocky growth habit, (2) low nutritive quality of forage, and (3) method of management fitted for the conversion of essentially wild, giant-sized forage species into manageable, high-producing, high-quality forage. Napier grass embodies all three features of the above-mentioned knotty problems. As a soilage grass it has the capacity to produce upwards of 40,000 pounds of total digestible nutrients (TDN) per acre per annum, enough TDN to support six 1000-pound animals for an entire year. As a pasturage, in contrast, an acre of Napier grass can barely sustain one animal. This amounts to only 16.7 percent utilization. As a soilage grass, whole Napier grass forage averages around 4 percent in protein content on an oven-dry basis, which makes its nutritive ratio about 1:18.6; this is more than double the ratio of about 1:8.0 recommended by Morrison *(18)*—far too wide for good nutrition without expensive supplemental protein feeding.

REVIEW OF LITERATURE

Because it is an important soilage crop, Napier grass has been studied in Hawaii mostly from the viewpoint of increasing its production of green forage or of determining its nutritive value and digestibility. Henke *(10)*, for example, showed that Napier grass produced the highest per-acre yields of total digestible nutrients (TDN—17,127 pounds) of the Hawaiian green roughages examined by him, but found that the digestible crude protein yield was relatively low (780 pounds per acre per year). Work *(31)* showed that a protein supplement was necessary to provide a properly balanced ration with mature Napier grass as well as with other forage grasses. Many studies have shown the feasibility of substituting strip cane *(13)*, pineapple tops *(12)*, and koa haole *(Leucaena leucocephala)* *(14)* for Napier grass in balanced dairy cattle rations.

Nordfeldt *et al.* *(19)* demonstrated the decline in digestible protein and TDN contents and the increase of crude fiber percentage with increase in age in Napier grass and compared these nutritive values in other forages. These authors also found that the economy of feeding Napier grass to dairy cattle depended on its cost of production relative to concentrate prices—a high level of Napier grass roughage being fed when the price of concentrate was high.

Wilsie and Takahashi *(30)* found Merker grass, a strain of *P. purpureum,* was slightly less palatable but not significantly differing in yield from standard Napier grass. They recommended that rows be spaced 6 feet apart and that the forage be harvested when 3 to 5 feet high to yield a high-protein forage. They found that the protein content declined from 14 percent in the plant crop to 3.8 percent in the sixth ratoon. Nordfeldt *et al.* *(19)* showed a decline in protein content with age at harvest (from 9.7 percent at 6 weeks to 4.6 percent at 15 weeks). In Australia *(9)* it was shown that crude protein reached 21 percent in young shoots, but declined to 7 percent when stalks were 7 feet high. South African workers *(17)* have stated that Napier grass was higher in protein in contrast to native grasses. Van Rensburg *(26)* found Napier grass compared favorably with other fodder plants in Tanganyika.

Time and height of cutting of Napier grass have been explored considerably *(5, 19, 20, 21, 27, 29)*, with the usual recommendation being to harvest every 8 to 10 weeks at a height of 6 to 10 inches above the ground to produce the highest yield of palatable forage and still maintain adequate tillering and ratooning. It has been shown that frequent cutting tends to decrease yields and to shorten the life span *(27)* of the crop.

Blaser *et al.* *(3)* reported protein and dry matter contents in Napier grass managed for grazing were higher than usual when managed for soilage. Intermediate digestible crude protein and starch equivalent values were found when immature Napier grass was fed as hay in East Africa *(7)*.

Low milk production in dairy cattle which were fed Napier grass has recently been attributed *(8)* to the high (2.01–2.57 percent) oxalate content of this grass.

Studies of Napier grass pasture fertilization in Hawaii *(32)* have shown that marked increases in forage yield and grazing capacity are due to nitrogen fertilization. Application of nitrogen fertilizer to Napier grass pastures was found to be especially valuable during drought periods for maintaining grazing capacity and forage production. Production of dry matter was doubled and yield of protein nearly tripled, resulting in profitable returns on fertilizer investment. In one trial, nitrogen applied at the rate of 132 pounds per acre per year produced 412 pounds of animal gain per acre per year as compared to 288 pounds of animal gain for the check paddock. In another pasture fertilization test, applications of 280 pounds of nitrogen per acre per year produced 468 cow-days[2] adjusted to 1000-pound units as compared to 266 cow-days for the check paddock.

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[2] There are several ways of expressing cow-days, or carrying capacity, which is one of the important criteria for assaying pasture productivity; but, in this publication, it is used in the following broad context: Cumulative number of heads of cattle, disregarding variations in individual weights, that can be supported under sufficient supply of grazeable forage that would assure normal weight gains commensurate with the capability of the given species from an acre of pasture during a year's time. In this publication it is termed, simply, carrying capacity. It may also be designated as cow-days/acre/year.

In Rhodesia *(1)* and Puerto Rico *(5)*, it was shown that strains of Napier and Merker grasses also responded to nitrogen fertilization up to 300 pounds per acre per year, while more recent studies in Puerto Rico *(16)* showed that irrigated and fertilized Napier grass produced more than 50,000 pounds of dry matter per acre per year. In this study, yields increased markedly with increasing rates of nitrogen up to 800 pounds yearly and the protein yield increased up to the 1600-pound-per-acre level, at which point the protein content was 11.4 percent, on an oven-dry basis. Maximum yields of 53,393 pounds of dry matter per acre per year were obtained with 1600 pounds of nitrogen per acre per year, but economic levels of production were in the 400- to 800-pound range.

Seasonal effects on growth have been observed in Trinidad *(20)* and Puerto Rico *(5)*. In Hawaii *(32)* it was found that somewhat higher gains and returns from nitrogen fertilization were experienced in wet rather than in dry years, but even under drought conditions, Napier grass showed a strong tendency to maintain production at 80 to 90 percent of normal. The species is considered to be an outstanding fodder for dry areas in Fiji *(22)*.

No responses to phosphorus or potassium have been recorded in Hawaii, but a highly significant response to 30 pounds of P_2O_5 per acre was obtained in Kenya *(6)*, and Burton and Lefebvre *(4)* have described potassium deficiency symptoms in Florida.

Grazing studies with Napier grass in Florida *(2, 3)* have produced daily gains of beef ranging from 1.4 to 1.6 pounds, depending on fertilizer treatment, during a grazing season of 165 to 175 days. In Uganda *(15)*, Napier grass rotationally grazed at a rate of one bullock per acre produced higher liveweight gains than Rhodes grass *(Chloris gayana)*, which was grazed at a height of 4 to 6 inches. Napier grass produced a linear liveweight gain during the year, while Rhodes grass produced a higher initial gain during February–June but then declined until November.

EXPERIMENTAL METHODS

Experimental Area

The tests were conducted at the Haleakala Branch Station, at an elevation of 2160 feet on the northwest slope of the extinct volcano, Haleakala, on the island of Maui. The mean monthly climatic data are given in table 1. The rainfall data indicate that this station has a moderately high annual rainfall, but its distribution is faulty. The monthly rainfall is somewhat deficient for 6 consecutive months from May through October, when temperature and sunlight conditions are most conducive for forage production. The mean annual temperature is 65.6° F; with the highest monthly mean maximum of 79.8° F recorded for the month of September and the lowest monthly mean minimum of 49.7° F recorded for the month of January. Extremes of temperature are rare, the long-term maximum being 83° F and the minimum, 45° F.

The temperature at this station is somewhat lower than the normal expectations for the elevation of 2160 feet. At any rate the mean annual temperature of 65.6° F is almost 10° lower than that recorded under sea level conditions. The materially lower temperature curtails considerably the productivity of nearly all tropical forage species, including Napier grass.

TABLE 1. Selected mean monthly climatic data for Haleakala Branch Station, Makawao, Maui

PRECIPITATION (INCHES)		TEMPERATURE (°F)		
Month	Mean*	Mean*	Monthly Mean Maximum†	Monthly Mean Minimum†
January	9.15	64.4	75.5	49.7
February	8.47	62.4	74.5	51.2
March	10.40	63.9	74.3	51.0
April	8.44	63.3	75.3	51.7
May	4.34	65.4	76.0	54.7
June	3.00	65.6	75.7	54.2
July	3.09	67.1	78.0	56.3
August	4.19	68.0	79.3	56.7
September	3.12	68.7	79.8	56.0
October	4.55	67.8	79.7	56.3
November	7.63	66.0	76.3	54.5
December	10.37	64.2	74.3	50.0
Annual	76.75	65.6	76.6	53.5

* Long-term means (36 years—1921 to 1957).
† Means for 6 years only (1951 to 1957).

The soil in the paddock area belongs to the Makawao silty clay loam, gently sloping phase (3 to 8 percent slopes) of the Makawao series in the Honolua family of the Humic Latosol great soil group. This site is near the border where the Honolua family intergrades with the Olinda family of the Latosolic Brown Forest great soil group. Both of the above families are deep, uniform soils that have weathered in place but are modified in varying degrees by the amount of ash deposits overlying them. The ash deposition in this experimental site is apparently negligible and its effects are nil. The soil of the experimental site is moderately acid (pH 5.5) with a low content of exchangeable bases. However, the soil is generally regarded as one of the better grazing-land soils in the Islands. The soil is quite friable and the topography is sufficiently gentle to allow the use of mechanical equipment without difficulty.

The improved pastures in the area are composed primarily of kikuyu grass *(Pennisetum clandestinum)* with about 25 acres in Napier grass in one ranch, whereas the unimproved pastures consist of a mixture of rattail grass (*Sporobolus africanus*—syn. *S. capensis*), Dallis grass (*Paspalum dilatatum*), and perennial foxtail grass (*Setaria geniculata*) with small amounts of rice grass (*Paspalum orbiculare*) and Hilo grass (*Paspalum conjugatum*). Guava (*Psidium guajava*) and joee (*Stachytarpheta australis*—syn. *S. cayennensis*) are the principal shrubby weeds.

Planting and Field Layout

The experimental paddocks and accompanying reserve paddock were plowed and disked before planting in late September, 1941. Napier grass eye-spot-resistant strain 34:33 was planted on 2.82 acres which were divided into three experimental paddocks, two of 0.62 acre each and one of 0.59 acre; and the remaining 0.99 acre was set aside for reserve paddock. The paddocks were shallowly furrowed out in paired rows with 3-foot spacings between members of a pair, and 7-foot spacings between two paired rows (fig. 1). The paired rows and the wide, interrow spacing between paired rows were adopted to minimize excessive matting of the tall stems. Two stem cuttings of two nodes each were placed in the bottom of the 6-inch furrows at 2-foot intervals and covered with 2 inches of soil. Each paddock was topdressed with ammonium sulfate at the rate of 150 pounds per acre after each grazing, except that in the spring, 150 pounds of "B" fertilizer (8–12½–6) were used in place of ammonium sulfate.

First grazing was initiated on August 20, 1942, almost a year after planting. Because of the long lapse of time between planting and first grazing, data on the first grazing were discarded. Grazing was terminated on July 2, 1948, almost 6 years after grazing was begun. Due to differential treatments, commencement and termination dates varied somewhat for each treatment.

Grazing Treatments

This grazing experiment was composed of three treatments: immature, short-grazing period; mature grazing, short-grazing period; and mature grazing, long-grazing period. The three systems used in this study may be characterized as follows:

I. Immature, Short-grazing Period

The plants were maintained in the immature state by mowing the residual standing growth back to ground level after the completion of each grazing (fig. 1). Thus, after each mowing, new stems and leaves were produced. Animals were turned into the paddock while the plants were still relatively young and succulent; at this stage the stems were 4 to 6 feet tall and were, essentially, subtended with green leaves only. All of the stems consisted of young, soft primary stems with no branching, aerial shoots. The forage in this treatment was kept at an immature stage by artificial manipulation and not directly through grazing management as such. Four animals were turned in at each grazing so as to consume the grazeable forage in approximately 3 weeks (fig. 2). On an acre basis the stocking rate was 6.78 animals.

II. and III. Mature Grazing—Short-grazing and Long-grazing Periods

This system of grazing was subdivided into two classes according to the length of the grazing period; otherwise, they were fairly similar. In the mature, short-grazing period system, 4 animals were turned in at each grazing so as to consume the grazeable forage in approximately 3 weeks, as in the immature system. In the mature, long-grazing period, 2 animals were turned in at each grazing so as to consume the grazeable forage in about 6 weeks, or twice as long as in the other two treatments.

In both of the above two treatments, the original plant crop was allowed to stand indefinitely during the 6 years of grazing during which time the paddocks were grazed 19 and 18 times for the mature, short-grazing and mature, long-grazing periods, respectively. In the immature system, grazeable forage was comprised of primary growth only, whereas in the two mature systems, grazeable forage was derived mainly from secondary, tertiary, etc., growths.

FIGURE 1. Regrowth of Napier grass 10 days after being cut back at completion of grazing (see figure 2) in the immature grazing system. Note the paired-row system of planting—3-foot row-spacing in the paired rows and 7-foot spacing between paired rows.

In both of the mature systems of grazing, grazeable forage was produced principally from two sources, new crown shoots and "lala" (fig. 3). When a clump of Napier grass is left undisturbed, new shoots are produced from the old crown from time to time. These new crown shoots are actually primary stems produced from an old crown. As in the case of primary stems produced in the immature system, the stems are large and soft and are subtended by large, normal leaves. New crown shoots are invariably current growths since after they are grazed,

FIGURE 2. Leaf blades were completely eaten during 3 weeks of grazing in the immature treatment but the stems were scarcely touched.

axillary aerial shoots are produced in the terminal sections. New crown shoots are then produced anew after each grazing, thus continuously renewing forage growth in the mature system of grazing.

"Lala" is a Hawaiian word used by Hawaiian stockmen to designate the primary, secondary, tertiary, etc., axillary shoots produced extensively on the terminal sectors of old stems and on new crown shoots after the terminal primordial sections of the shoots have been foraged off by grazing animals (see figures 4 and 5). Lala is quite distinctive from new crown shoots; lala is an axillary aerial shoot whereas crown shoots are ground shoots or suckers. Lala is also morphologically quite distinctive as well. The internodes are usually extremely short; so much so, that the shoots often assume a rosette type of growth. The leaves are materially shorter and narrower and in time the lala branches and rebranches so freely that it often becomes fasciculate.

Inevitably, under grazing, some of the stems are trampled or become so top-heavy with greatly proliferated lala growths that they arch over and come in contact with the ground. If conditions then are favorable, these prostrate stems strike root, and new shoots are produced at the nodes. Shoots produced from prostrate stems

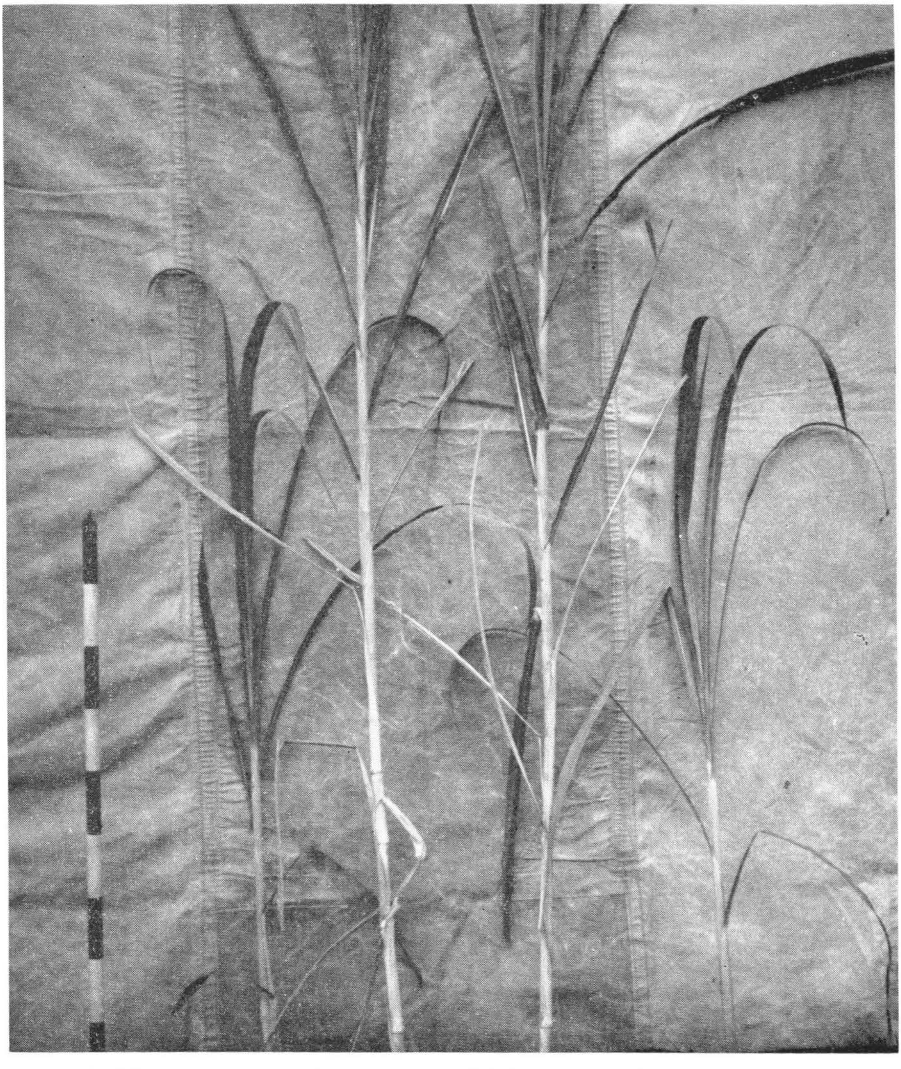

FIGURE 3. New crown shoots of Napier grass of different derivation. The two center robust shoots were produced from stools, while the two small, spindly shoots, on either side, were produced from fallen stems. The marker divisions are graduated in 4-inch sections.

are termed "fallen-stem shoots." They are usually thin and slender. In the mature system of grazing, forage production is a mixture then of (1) old woody stems with their subtended lala, (2) new crown shoots, and (3) fallen-stem shoots.

The above three grazing treatments can be regrouped and reclassified into two classifications as follows:

A. Short-grazing period (immature, short-grazing and mature, short-grazing treatments) vs. long-grazing period (mature, long-grazing treatment).

FIGURE 4. Leafiness in lala increases with age. *Left,* first generation lala; *right,* leafy and fasciculated growth of advanced generation lala.

B. Moderate stocking rate (6.78 and 6.45 animals on an acre basis for the immature and mature, short-grazing treatments) vs. light stocking (3.23 animals on an acre basis for the mature, long-grazing period). This latter method of grouping, strictly speaking, is a restatement of the above classification inasmuch as the length of grazing period is a function of stocking rate and vice versa.

Forage Yields and Segregation

In this grazing test, a two-pronged attack was made to evaluate the results of grazing treatments; namely, measurements on animal production and quantitative

FIGURE 5. Close-up of second generation lala, showing proliferating shoot production. Note the greater leafiness, smaller leaf size, and shorter internodes than in new shoots, in figure 3.

determinations of before- and after-grazing forage production. Due to the differences in growth habits induced by grazing treatments, different harvesting and forage separation techniques were used to meet the specific requirements of the individual treatments.

Harvesting data were taken from 10 pairs of 10-foot $\times$ 10-foot quadrats which were laid out at random prior to the start of grazing. "Before-grazing" data were taken by "harvesting" one quadrat from each of the 10 paired quadrats just before

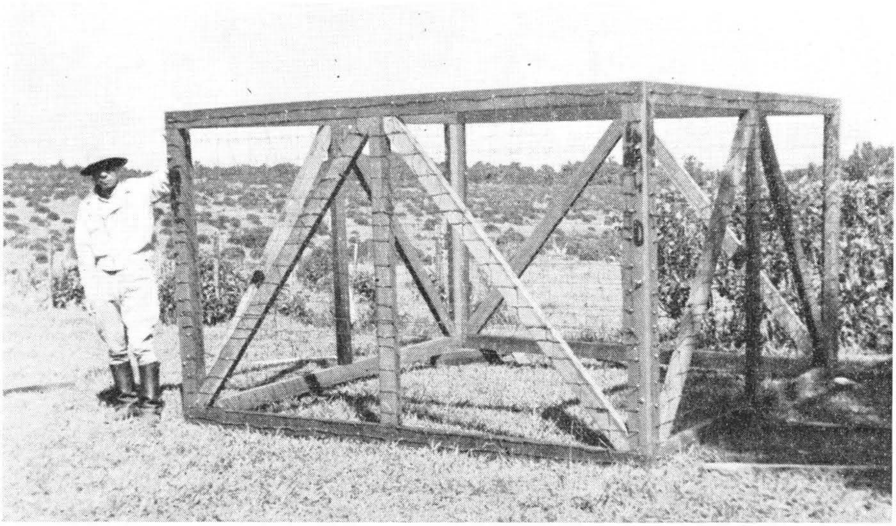

FIGURE 6. Sturdy, open-top, 10-foot × 10-foot wooden-frame quadrat used in grazing management studies.

grazing was started. "After-grazing" data were taken by harvesting the remaining members of the paired quadrats immediately after completion of grazing. Quadrats were re-allocated for each grazing. In the immature, short-grazing and mature, short-grazing treatments, uncaged quadrats were used, but in the mature, long-grazing treatment, the quadrats were enclosed in 10-foot × 10-foot, open-top, screened, wooden-frame cages, 6 feet high (fig. 6).

I. Immature, Short-grazing Period

In the immature, short-grazing treatment, all harvests were made by harvesting the quadrats at ground level. The before-grazing harvest consisted of only a single growth type, the primary shoots. During grazing, some of the shoots were knocked down and trampled by the grazing animals. In the after-grazing harvest, separate harvests were made of the trampled and standing shoots. The difference between the before- and after-grazing total forage yields represents the amount of forage ingested by the animals. As the grazing period extended for about 3 weeks, no attempt was made to assess growth increment made during the period.

In all harvests, forage was separated into "leafy" and "stemmy" portions (fig. 7). Leafy portions comprise all the green leaves and the meristematic apical part of the stem, down to and including the first elongated internode. The difference between whole forage and leafy portions constitutes the stemmy portion. All dried leaves attached to stems are included in the stemmy portions. With a large, tall, tussocky tropical grass such as Napier grass, the leafy portions represent very closely the total grazeable portions.

II. Mature, Short-grazing Period

In this treatment, new crown shoots and fallen-stem shoots were harvested separately by cutting at nearly ground level, as was done with primary shoots in

FIGURE 7. Pre-grazing harvest of immature grazing treatment segregated into leafy (*left*) and stemmy (*right*) portions.

the immature, short-grazing treatment. Lala was harvested by cutting close to the node of the parent stem, leaving about a 2-inch stubble for subsequent regeneration of lala. (See figures 8 and 9.)

III. Mature, Long-grazing Period

Further modifications in harvesting were made to fit the conditions of this treatment. Because of the materially longer grazing period, it was felt that a significant amount of new growth accretion took place during grazing. In order to assess the growth increment made during the long-grazing interval, split-harvest

FIGURE 8. Mature, short-grazing-period treatment paddock shortly after commencement of grazing. Due to good growing conditions, the bulk of the forage consists of new crown shoots; normally they constitute 41.1 percent of the forage production. See figure 9 for grazing results after 7 days of grazing.

data were taken in three increments. The first increment was taken approximately 3 weeks after the start of grazing, and the other two remaining increments were taken right after completion of grazing. In the first two harvestings, harvesting consisted of removing, by hand, leafy portions only to the same degree as those that had been grazed off in the outside plot during the grazing interval. Since this forage harvesting in the first two increments was done by "plucking off," by hand, amounts equivalent to the leafy portions that had been grazed off by animals, this method of hand harvesting for the determination of the amount of forage ingested has been termed "plucking." After the second plucking was taken at the end of the grazing period, the remaining ungrazed leafy portions were then stripped off and the remaining stemmy portions were then harvested. The sum of the first two pluckings constitutes the amount of forage ingested. This sum plus the ungrazed

FIGURE 9. Grazing pattern of mature, short-grazing paddock shown in figure 8, seven days after the start of grazing. In the early stages of grazing, the tips of the leaf blades are grazed off first.

leafy portions make up the grazeable forage. The sum of the grazeable forage, and the stemmy portions by indirection, constitute the before-grazing total forage yield.

Chemical Analyses

Dry matter and protein contents were determined only for a limited number of samples, as it appeared that the supplemental information that could be derived from the analyses of every sample was far out of proportion to the large expense required to run some 1500 analyses.

Animal Selection and Care

All animals used in this study were furnished by the Haleakala Ranch Company[3] or by the Haleakala Dairy. Since the animals were furnished on loan, it

[3] Appreciation is expressed to Haleakala Ranch Company and to Haleakala Dairy for the use of animals and for generous help in handling them.

was not possible to control either the size of the animals used on experimental paddocks or to maintain the animals for any specific length of time. As a result, there was a hodgepodge of animals with which to contend. Grade Hereford steers were used for the first 11 grazings, and Holstein heifers for the last 6 grazings. The initial weights of the animals used in the experiment varied widely from a low of 220 pounds to a high of 775 pounds, with a mean weight of 521 pounds. Likewise, animals were withdrawn from test paddocks at weights varying from 420 to 895 pounds, with a mean of 698 pounds. The original project outline called for animals with starting weights averaging around 450 pounds, and for carrying them along until they attained a marketing weight of around 1000 pounds. As indicated above, the actual execution deviated considerably from the original experimental plan.

During the 6 years of grazing, 33 animals were used, and their tenure in the experimental paddocks ranged from 27 to 366 days, with a mean of 119 days.

The original intent was to keep the animals entirely on Napier grass forage, but because the supply was inadequate, the animals were grazed, from time to time, on nonexperimental paddocks containing different types of pure and mixed pasture species. During the duration of the experiment, the animals were on Napier grass experimental paddocks 61.3 percent of the time. All animals were grazed rotationally on the three treatments.

During the first 11 grazings, modest amounts of supplemental feeds were given. Each animal was given an average of 2.39 pounds of sugar cane molasses per day. The daily consumption per animal varied from 0.79 to 4.62 pounds. Soybean meal at the rate of 1 pound per animal per day was provided along with the molasses for the first 11 grazings. Both molasses and soybean meal were deleted for the last 6 grazings. During the entire course of grazing, the animals were given free access to bonemeal and salt.

Animals were weighed at the beginning and at the end of each grazing period. Double weights were taken, i.e., in the evening, and again in the morning after the animals were penned without feed or water. The second weights without fill were used in calculating weight gains.

RESULTS AND DISCUSSION

Animal Production

Animal Variability

Since all 33 animals used in this experiment were on loan from Haleakala Ranch Company (Hereford steers) or from Haleakala Dairy (Holstein heifers), it was not possible to exercise much control over either the initial weights of the cattle or their tenure in the experimental pastures. The plan of the experiment was to start with 8- to 10-month-old feeder steers weighing around 450 pounds and to carry them through maturity up to around a 1000-pound weight. However, the animals provided by the ranch and dairy came in at weights ranging from 220 to 775 pounds with an average of 521 pounds. The initial weights of nine of the animals were under 400 pounds, and nine weighed more than 600 pounds.

The animals were taken back by the owners at weights ranging from 420 to 895 pounds. Sixteen were taken back at weights under 700 pounds, and only seven weighed more than 800 pounds. With the exception of one animal that weighed 895 pounds, none of the animals were near the desired marketing weight of 1000 pounds when they were taken back. Animals were taken back at an average weight of 698 pounds, while they were still making adequate daily gains.

Because many animals came in at an advanced weight and some were taken back long before attaining marketing weight, many of them had short tenure in the experimental paddocks. Tenure in the paddocks ranged from 27 to 366 days with a mean of 119 days. The tenure of 12 of the animals was less than 50 days and only 5 exceeded 200 days.

Since the animals varied considerably in all aspects, doubt might be cast on the reliability of the animal data, but careful scrutiny of the data indicates that the results have a high degree of accuracy. For example, of the 12 animals that had tenures of less than 50 days, the calculation of daily liveweight gain for this group showed no adverse effects from short tenure, as the daily gain was 1.04 pounds while the average for all animals was 1.00 pound. There was also little relation between the size of animals and daily liveweight gains.

The reliability of animal data in this experiment was strengthened by the fairly large number of animals and the large number of grazings used. Furthermore, animal productivity was substantiated by forage production, as will be shown in the latter part of this bulletin.

Animal Management

1. Resting or growth-recovery period

The resting or growth-recovery period varied widely in all three treatments. Figures are presented in table 2 together with other management schedule data. The range in time for the growth-recovery period was especially pronounced in the mature, long-grazing treatment. In this treatment, the longest resting period was three times as long as the shortest resting period. There was practically no difference in the range of the resting period between the immature, short-grazing and the mature, short-grazing treatments, the range being approximately 1.8 times. Of all the measurements recorded, the greatest fluctuations were registered in the range of the resting period. The wide range in the length of the growth-recovery period probably indicates that the growth-recovery rate is more sensitive than any other productivity measurement to changes in weather conditions. The effect of weather conditions on both forage production and animal production was not as pronounced as was expected. In the mature, short-grazing treatment it was found that the deviations from the means of the length of rest periods for the 6 winter and the 6 summer periods were 16.7 and 17.7 percent, respectively.

The mature, long-grazing treatment was expected to have the longest rest period, but contrary to expectation, the rest period was 33.2 percent shorter than the mean of the two short-grazing treatments. Because this treatment was subjected to light grazing, it was expected that the range in recovery period would be relatively narrow; as it turned out, however, it had the widest range in recovery period.

On the other hand, the rest period of the immature, short-grazing period was materially longer than expected. A study of the management data indicates that the treatment designated as an immature system is somewhat of a misnomer. Grazing of the immature, short-grazing period paddock after a growth-recovery period ranging from 81 to 148 days, with a mean of 109 days, is anything but

TABLE 2. Grazing management schedule for Napier grass grazing treatment studies, Haleakala Branch Station

TREATMENTS	Paddock Size in Acres	No. of Animals per Paddock	No. of Animals on Acre Basis	Total No. of Grazings	No. of Grazings per Year	Total No. of Days Paddocks Grazed per Year	Percent of Time Paddock Under Grazing	No. of Resting Days per Grazing Cycle		No. of Days Grazed per Grazing Cycle		No. of Days per Grazing Cycle	
								Range	Mean	Range	Mean	Range	Mean
Immature, short-grazing	0.59	4	6.78	17	2.89	50.3	13.8	81–148	109.0	13–20	17.35	95–166	126.4
Mature, short-grazing	0.62	4	6.45	18	3.10	56.2	15.4	79–142	99.8	10–23	17.89	98–162	117.7
Mature, long-grazing	0.62	2	3.23	17	3.03	139.5	38.2	46–139	77.6	27–72	42.80	86–174	120.4
Mean				17.3	3.01	82.0	22.5	69–143	95.5	17–38	26.01	93–167	121.5

immature from the standpoint of number of days of growth. While it is true that the immature system was grazed when the plants were apparently morphologically immature, the plants ranging in height from 4 to 6 feet (at which stage the accretion of dry leaves was still at a minimum), the fact remained that this treatment was at times grazed when the plants were quite advanced in age for primary stems, the maximum being 21.1 weeks. Twenty-one-week-old primary stem Napier grass can hardly be classed as immature, according to experience with this grass as a soilage crop. During a 4-year period, 1941 to 1945, a frequency-of-cutting experiment was carried on with heavily fertilized Napier grass in a nearby area. Treatments consisted of harvests made every 9, 12, 15, and 18 weeks. In this test, harvests made every 9 weeks were termed immature; those made every 15 weeks, mature; and those cut every 18 weeks, past mature. Under such a classification, the forage growth of immature, grazing treatment averaging 15.6 weeks in age at the start of grazing would be classed as mature growth. Nevertheless, this treatment was considered "immature" in the sense that the forage growth at the commencement of each grazing was comprised of forage that had been regenerated anew after each grazing, and current growth consisted entirely of succulent primary shoots, characteristic of immature growth. In contrast, the forage growth in the mature systems of grazing was composed of a conglomeration of various types of forage growths of varying ages, which had been produced on or from original crown growth that was established in 1941.

Data on the number of days in the resting period for all treatments show considerable range, the longest interval being almost twice as long as the shortest. Even greater range is recorded in the number of days grazed per grazing cycle, the greatest range being 27 to 72 days for the mature, long-grazing period. The wide range in grazing schedule was due to the growing of Napier grass in climatically marginal areas coupled with the considerable range in the seasonal march of climate which is prevalent at the Haleakala Branch Station. During the fall and winter months of October to March, growth can be drastically curtailed by cold weather, which often becomes aggravated when it is accompanied by either excessively dry or wet weather. During the summer months, growth is often impeded by long spells of dry weather.

At best the Haleakala Branch Station (2160 feet elevation) is on the lower limits of temperature for the economic production of Napier grass. Experience with the growing of Napier grass from sea level to the 2200 feet elevation has indicated that its productivity at the latter elevation is about 60 percent of that at sea level. Marked differences in temperatures between sea-level conditions and those at the Haleakala Branch Station are clearly depicted in table 3.

2. *Number of days grazed per grazing*

Due to the nature of the treatments, the difference in the number of days grazed per grazing cycle between the long-grazing and the short-grazing periods was clear-cut. Since the number of days of grazing in the long-grazing treatment was more than double the mean of the two short-grazing treatments, the difference must be due to something other than the direct effect of the difference of the 1 to 2 ratio in stocking rates. Measured on a cow-day basis, the length of grazing period of the long-grazing treatment was 21.4 percent higher than the mean of the short-grazing treatments.

TABLE 3. Comparative temperature data, sea level Honolulu, Oahu, vs. Haleakala Branch Station

LOCATION	ELEVATION	MEAN ANNUAL TEMPERATURE	LOWEST MONTHLY MEAN MINIMUM	HIGHEST MONTHLY MEAN MAXIMUM
	feet	°*F*	°*F*	°*F*
Honolulu, Oahu	12	74.6	64.0	84.5
Haleakala Branch Station, Maui	2160	65.6	49.7	79.8

Because of the light stocking rate, the mature, long-grazing treatment was under grazing for a considerable part of the year. Both of the short-grazing treatments were under grazing for about 14.6 percent of the time as compared to 38.2 percent for the long-grazing treatment.

3. Number of grazings per year

The number of grazings per year was quite low and the differences between treatments were small and nonsignificant. Although there were wide differences between treatments in the various phases of management, the differences tended to cancel out each other so that the end-product, number of grazings per year, came out nearly the same in all treatments.

Animal Production

1. Carrying capacity

Data on animal production are presented in table 4. The overall carrying capacities of all three treatments were quite satisfactory. The differences in carrying capacities between treatments were quite high; but, because of the lack of replications and the high percentage of the coefficient of variation, the differences were either not statistically significant or were significant only at low levels of probabilities. Comparison between the immature and the two mature systems showed a difference of 26.0 percent, whereas the difference between the two short-grazing treatments and the long-grazing treatment was 32.6 percent, or almost a third larger.

2. Daily gains

The average daily liveweight gains per animal was just fair, and the differences between treatments were small and nonsignificant. The largest difference was between immature, short-grazing and mature, long-grazing, the respective daily gain figures being 0.92 and 1.11 pounds, a difference of 20.7 percent.

Inasmuch as the average daily gain was 1.00 pound, at this rate of daily gain, 8- to 10-month-old feeder steers weighing around 450 pounds would require 550 days of grazing to attain a marketing weight of 1000 pounds. At this rate of weight gain, the finished steers would be 26 to 28 months old at the time of marketing. While the marketing of steers at 26 to 28 months of age may be commendable, the gain may not be rapid enough to ensure the production of tender, high-quality beef under grass feeding alone. Steers produced and finished for high quality on grass feeding alone should attain a marketing weight of around 1000 pounds,

TABLE 4. Animal production data on Napier grass grazing management studies over a 6-year period, Haleakala Branch Station

YEAR	IMMATURE			MATURE						MEAN OF TREATMENTS		
				Short-Grazing Period			Long-Grazing Period					
	Carrying Capacity	Daily Liveweight Beef Gain in Pounds per Animal	Liveweight Beef Production in Pounds per Acre/Year	Carrying Capacity	Daily Liveweight Beef Gain in Pounds per Animal	Liveweight Beef Production in Pounds per Acre/Year	Carrying Capacity	Daily Liveweight Beef Gain in Pounds per Animal	Liveweight Beef Production in Pounds per Acre/Year	Carrying Capacity	Daily Liveweight Beef Gain in Pounds per Animal	Liveweight Beef Production in Pounds per Acre/Year
1943	415	1.46	606	418	0.80	334	591	1.36	804	475	1.21	581
1944	261	0.29	76	254	1.29	328	419	0.85	356	311	0.78	253
1945	326	1.03	336	470	0.55	258	560	0.85	476	452	0.81	357
1946	301	1.02	307	339	0.73	247	436	0.91	397	359	0.89	317
1947	306	1.40	428	331	1.17	387	336	1.14	383	324	1.24	396
1948	298	0.31	92	326	1.32	430	342	1.54	527	322	1.06	350
Average	318	0.92	308	356	0.98	349	447	1.11	490	374	1.00	374

preferably at less than 24 months of age. If 1000-pound steers are produced at this young age, the meat is bound to be quite tender, light colored, and with enough fat to give it good flavor. In order to finish-off steers under pasturage alone at 24 months of age or under, feeder steers 8 to 10 months old and averaging around 450 pounds in weight must make an average daily gain of 1.50 pounds. At this rate of daily gain, the steers will attain the marketing weight of around 1000 pounds in 12 months of grazing and will be 20 to 22 months old.

The small differences in daily gains between treatments probably imply that the quality of the forage ingested by animals was just about the same for all treatments. The year-to-year variations were quite marked, but no trends were discernible. Studies on the relationship between daily gain and factors such as initial weights of animals, tenure of animals, and rainfall showed wide fluctuations, and indications of trends were noted in the relationship between daily gain and the latter two measurements. Twenty-six animals with tenure of less than 160 days had an average daily gain of 0.878 pound as compared to the average daily gain of 1.247 pounds for the seven animals with tenure ranging from 160 to 366 days. The difference in gain between the two groups was 42 percent, indicating that long tenure results in higher daily gain. On the basis of a classification of annual rainfall for the 6-year period into three groupings of less than 50, from 51 to 75, and more than 75 inches, a comparison of daily gain figures showed that daily gain increased with an increase in rainfall, the comparable figures being 0.621, 1.173, and 1.331 pounds, respectively. Within any one group, however, sharp differences were noted. For example, in the group with an average annual rainfall in excess of 75 inches, rainfall during a grazing cycle ranged from 29.05 to 55.94 inches and daily gains ranged from 0.312 to 1.562 pounds. Contrary to general experience, for some unknown reason, there was no correlation between initial weights and daily gains.

3. *Beef production per acre per year*

Beef production per acre per year, which more commonly is stated simply as beef production, is the arithmetical product of carrying capacity and daily gain. It is the ultimate criterion for the evaluation of pasture productivity. In this experiment, both the carrying capacity and the daily gain figures showed significance only at low levels of probability of exceeding $P = 0.11$. However, despite the lack of statistical significance, the trends in both measurements were similar and since their products were additive, the differences in beef production between treatments were distinct. In the short- versus long-grazing treatment comparison, the latter treatment had a significantly higher productivity of 50.9 percent over the former treatment. A comparison made on the basis of maturity showed that the mean of the two mature treatments indicated that beef production was 36.8 percent higher than the immature treatment.

Beef production averaging 496 pounds per acre per year over a 6-year period by the mature, long-grazing treatment is a noteworthy performance for any pasture sown to a single grass species. According to published yield data in *(28)*, an equivalent of 42,189,000 pounds of beef on a liveweight basis was produced in 1961 from 1 million acres of pasture lands in Hawaii. Even after allowances are made for nonproductive breeding herds, young calves, and the many thousands of acres of worthless and marginal pasture lands included in the acreage figure, the production figure in the present experiment is at least twice as high as the state-wide production. The high production figure in this test is thus even more significant than the results indicate, because it was obtained in a climate that is marginal for the growing of tropical grasses like Napier grass. The outstanding beef production of 804 pounds for the first year's production in the mature, long-grazing treatment indicates that under adequate fertilization and during years with more favorable rainfall distribution, beef production from Napier grass pasture could be even higher.

Comparisons with Other Grazing Tests on Napier Grass

Since this grazing experiment was terminated, two other grazing experiments with Napier grass pastures were conducted by the Hawaii Agricultural Experiment Station.

According to Younge and Ripperton's *(32)* report on Napier grass grazing tests conducted at Haiku, Maui, (elevation 300 feet) in 1950–1952, the average number of cow-days and beef production in pounds for fertilized (115 pounds of nitrogen per acre per year) and unfertilized paddocks were, respectively, 200 and 136 cow-days and 385 and 269 pounds of beef. These paddocks were grazed rotationally, 6 times per year. The respective carrying capacities for the fertilized Haiku tests and the mature, long-grazing treatment were 200 and 273 (corrected to 1000-pound-animal basis) cow-days, a superiority of 36.5 percent in favor of the present test. In beef production, the mature, long-grazing treatment exceeded the fertilized Haiku paddock by 16 percent, the respective beef production being 447 and 385 pounds. The daily gains were 1.9 pounds for the fertilized Haiku paddock and 1.82 (corrected to 1000-pound-animal basis) pounds for the mature, long-grazing treatment.

Except for daily gain, the mature, long-grazing treatment had production figures that were higher than those of the fertilized Haiku paddock. The differences may be significant only in carrying capacity; but, taking into consideration the difference in growing conditions between the sites, the performance of the mature, long-grazing treatment appears quite noteworthy inasmuch as the Haiku pasture enjoyed an advantage in growing conditions of about 30 percent due to materially higher temperature, lower incidence of cloudiness, and, at the same time, rainfall was comparable.

Any comparison between this present test and the grazing test on the response of Napier grass pasture to levels of nitrogen that was also conducted at the Haleakala Branch Station by Younge and Ripperton *(32)* is difficult to make because the data are not comparable. In the mature, long-grazing treatment, the number of grazings per year was 3.03, whereas the mean number of grazings per year for the check paddock in Younge and Ripperton's trial was 4.11, a difference of 36.5 percent. These authors noted practically no difference in the number of grazings per year for the check plot between the wet year in 1950 when rainfall was 82.9 inches, and the dry years in 1949, 1951, and 1952, when rainfall averaged 33.1 inches, the respective number of grazings per year being 4.18 and 4.06. These authors stated that even in very dry months, for example May to September, when rainfall may drop to less than 1 inch per month, forage production remains at 80 to 90 percent of wet-period production.

In a Napier grass grazing test conducted in Florida, Blaser *et al.* (2, 3) obtained, respectively, 227 and 170 cow-days, daily gains of 1.7 and 1.56 pounds, and beef production of 386 and 263 pounds on Napier grass pastures in which one set was fertilized with 400 pounds per acre per year of 5–7–5 fertilizer plus a supplemental application of 75 pounds of sodium nitrate and the other set was fertilized with 400 pounds per acre per year of 5–7–5 fertilizer. The above treatments were under test for 164 and 173 days during the year, respectively. With the exception in daily gains, other production figures are below Hawaii's results due to the restricted grazing season in Florida. However, in a comparison based on identical lengths of grazing seasons, Florida's results surpass those obtained here by a considerable margin. If the results obtained in Florida were to be converted on a year-long basis, the respective results for the two fertilizer treatments would be as follows: carrying capacity—505 and 358 cow-days; and beef production—859 and 560 pounds of liveweight beef gains.

Although better results were obtained in Florida on a per-unit-of-time basis, on an annual basis, Hawaii's results enjoy a considerable margin over Florida's because of the limited production period there. Hawaii, along with the rest of the tropical world, enjoys considerable advantage over temperate areas in beef production because Hawaii's year-long growing season is more than twice as long.

The various results on Napier grass pasture investigations show conclusively that even under conditions of stress, Napier grass somehow is able to maintain productivity at a fairly even keel. Under Haleakala Branch Station conditions, it surpasses other pasture species by far in its ability to come through adverse weather conditions in good shape. This is even more remarkable when it is considered that the Haleakala Branch Station is situated at the upper limits in elevation for the culture of Napier grass.

The ability of Napier grass to weather adverse conditions, particularly lengthy periods of drought, should make it one of the leading grasses for pastures between 1000 and 2500 feet elevation. If nothing else, it still could be utilized advantageously as reserve paddock for use during dry periods when forage production in other grasses takes a sharp drop because of drought. The high degree of resistance of Napier grass to drought, however, holds true only if it is utilized as pasturage on cooler midlands at elevations of 1000 to 2500 feet.

The present experiment indicates that under Haleakala Branch Station conditions, Napier grass ranks among the best pasture species in animal production. Its unquestionable ability to maintain its productivity through cold spells as well as dry spells is an additional asset of this rank-growing robust grass. Under the three systems of grazing studied, it proved conclusively its ability to retain its productivity and persistence through 6 years of trial.

General Comments on Animal Production

In all animal production measurements, the first year's results were outstanding; this was particularly true in the mature, long-grazing treatment. The first year's results on animal production for this treatment were: carrying capacity, 591 cow-days; daily gain, 1.36 pounds; and beef production, 804 pounds. The differences between the first and the second year's results were clear-cut. In carrying capacity and daily gain, the first year's results were 52.7 percent and 55.9 percent higher than those of the second year, respectively. Liveweight beef production, which is the product of carrying capacity and daily gain, was 2.3 times as high.

Data on grazing management as well as animal production for the 6 years of testing show that after the excellent results of the first year, animal production dropped and continued to fluctuate for the remaining 5 years, but there was no indication of a linear drop in production due to aging of the pasture sward. As far as Napier grass persistence was concerned, all three treatments showed no decrease. Not only does the stability in animal production indicate that there was no decline in forage production with aging of the pasture stand, but, also, the consistency in daily gain over the years indicates that the forage quality remained fairly constant.

Although the long-range findings were conclusive, the individual data at times fluctuated almost as violently as a roller coaster. Because of these wide fluctuations, no clear correlations could be established between any two factors. To indicate some of the conflicting forces at work, detailed animal data for the grazing of the mature, short-grazing treatment are presented in table 5.

The overall performance of the present experiment may be evaluated in yet another way. Since the reserve Napier grass paddock was grossly inadequate for taking care of the animals between grazing rounds in the experimental paddocks, the animals were shunted from time to time to paddocks containing other grasses. During the 6-year period, the experimental animals were grazed on other grasses approximately 40 percent of the time. The 33 animals used during the 6 years of testing recorded a total liveweight gain of 5863 pounds, of which 1802 pounds were made in other nonexperimental paddocks. An examination of the animal disposition shows that they grazed on nonexperimental paddocks for a total of 2481 cow-days. Calculations of daily gain made on miscellaneous forage species showed an average daily gain of 0.726 pound. Thus, the daily gain on miscellaneous forage species was approximately 30 percent less than the gain made on Napier grass. A difference of this magnitude is probably quite significant, and indicates that Napier grass is among the top-ranking tropical grasses for tropical pastures, which generally are conceded to be pastures located below 3000 feet elevation in Hawaii. During the 6-year period, the experimental animals were grazed for 40 percent of the time on the following 11 pasture species and combinations: 7 grass species—Bermuda, Dallis, *Digitaria pentzii,* kikuyu, molasses, para, and Rhodes grasses; 1 grass mixture—Napier-kikuyu; 1 legume—Spanish clover *(Desmodium sandwicense);* and 2 grass-legume combinations—pigeon pea–Rhodes grass and pigeon pea–molasses grass. As all of the above-mentioned species are highly esteemed tropical pasture species, the 30 percent higher animal production obtained in this present grazing test with Napier grass is an eloquent endorsement of Napier grass for tropical pastures—high animal production, consistent performance over a period of years, and a high degree of drought resistance.

Effects of Supplemental Feeding

1. Molasses supplement

Supplemental feeding of sugar cane molasses and soybean oil meal was provided as a blanket application during the first 10 grazings, but was discontinued thereafter for the last 3 years of the test. The amount of molasses consumption was planned at 2 pounds per animal per day; but the amount of molasses actually

TABLE 5. Detailed animal data for mature, short-grazing treatment, Haleakala Branch Station, 1942–1948

YEAR	GRAZING NO.	DATE OUT	DATE IN	NO. OF DAYS REST	NO. OF DAYS GRAZED	NO. OF DAYS PER GRAZING ROTATION	NO. OF GRAZINGS ON ANNUAL BASIS	NO. OF COW-DAYS PER GRAZING	TOTAL WEIGHT GAINS IN POUNDS PER GRAZING	MEAN DAILY GAINS IN POUNDS PER ANIMAL	BEEF PRODUCTION IN POUNDS PER ACRE PER YEAR	RAINFALL IN INCHES, DURING GRAZING CYCLE	RAINFALL IN INCHES ON ANNUAL BASIS
1942		12–21–42	12–1–42	81	20	101	3.29	80	62	0.775	329	22.07	
1943	3	4–29–43	4–8–43	108	21	129	2.83	84	110	1.309	501	33.40	
	4	8–13–43	7–21–43	83	23	106	3.44	92	100	1.086	554	16.89	
	5	11–19–43	11–4–43	83	15	98	3.72	60	0	0	0	5.67	
	Average			91	20	111	3.33	79	70	0.80	334		55.96
1944	6	3–13–44	2–26–44	99	16	115	3.17	48*	105	2.187	536	22.62	
	7	7–13–44	6–28–44	107	15	122	2.99	60	35	0.583	168	16.11	
	8	10–24–44	10–14–44	93	10	103	3.54	40	33	1.100	251	5.66	
	Average			100	14	114	3.23	49	61	1.29	328		44.39
1945	9	3–5–45	2–13–45	112	20	132	2.77	60*	10	0.125	446	14.96	
	10	6–25–45	6–2–45	89	23	112	3.26	92	45	0.489	236	19.23	
	11	9–12–45	9–12–45	79	19	98	3.72	76	80	1.053	480	14.98	
	Average			93	21	114	3.25	83	45	0.55	258		49.17
1946	12	1–21–46	1–4–46	95	17	112	3.26	68	35	0.515	184	14.39	
	13	4–23–46	4–11–46	80	12	92	3.97	48	15	0.312	96	35.64	
	14	9–19–46	8–26–46	127	22	149	2.45	88	120	1.364	475	17.16	
	Average			101	17	118	3.23	68	57	0.73	247		67.19

(*Continued*)

TABLE 5. Detailed animal data for mature, short-grazing treatment, Haleakala Branch Station, 1942–1948 (*continued*)

YEAR	GRAZING NO.	DATE OUT	DATE IN	NO. OF DAYS REST	NO. OF DAYS GRAZED	NO. OF DAYS PER GRAZING ROTATION	NO. OF GRAZINGS ON ANNUAL BASIS	NO. OF COW-DAYS PER GRAZING	TOTAL WEIGHT GAINS IN POUNDS PER GRAZING	MEAN DAILY GAINS IN POUNDS PER ANIMAL	BEEF PRODUCTION IN POUNDS PER ACRE PER YEAR	RAINFALL IN INCHES, DURING GRAZING CYCLE	RAINFALL IN INCHES ON ANNUAL BASIS
	15	1–14–47	12–28–46	100	17	117	3.12	68	95	1.397	478	55.94	
	16	6–25–47	6–5–47	142	20	162	2.25	80	115	1.438	417	28.43	
1947	17	10–14–47	9–27–47	94	17	111	3.29	68	45	0.662	239	13.30	
	Average			112	18	130	2.89	72	85	1.17	387		97.67
	18	2–13–48	1–29–48	107	15	122	2.99	60	65	1.083	313	58.27	
1948	19	6–22–48	6–2–48	122	20	142	2.57	80	125	1.562	519	29.07	
	Average			114	18	132	2.78	70	95	1.32	430		
Mean				100	17.9	117.9	3.10	70.1	67.4	0.98	349	—	62.9

* In these 2 grazings, 3 instead of 4 animals were stocked in the paddock.

consumed daily by each animal varied from 0.79 to 4.62 pounds and the mean was 2.39 pounds. Since the difference in the number of animal-days in the treatments was not taken into account, the total amount of molasses given during the duration of supplemental feeding to each treatment varied considerably, the amount being closely proportional to the number of cow-days in each treatment, which was 318, 356, and 447 for the immature, short-grazing; mature, short-grazing; and mature, long-grazing, respectively. The total amount of molasses consumed in each of the three treatments was 1677, 1956, and 2412 pounds, and the amount consumed per animal per day was 2.236, 2.569, and 2.359 pounds, respectively. The total amount of molasses consumed in the mature, long-grazing treatment was 43.8 percent greater than in the immature, short-grazing treatment, but the difference in consumption per animal per day was only 5.5 percent.

As no check animals were provided and since a supplement of soybean oil meal was given at the same time also, there is no valid way of assessing the effect of the molasses supplement on animal production. However, a calculation of theoretical intake of TDN indicated that molasses did contribute enough TDN to exercise some influence on animal production. According to Morrison's *(18)* feeding standard, the mean daily TDN intake of a rapid-growing beef animal weighing 610 pounds (median weight of animals in this test) is 9.2 pounds. Of this amount, the 2.39 pounds of molasses contributed 1.35 pounds of TDN (percent TDN of molasses at 56.6 percent) which amounted to 14.67 percent of the total TDN or an equivalent of one-seventh of the TDN intake.

To ascertain the effect of a molasses supplement on animal production, comparisons were made on carrying capacity and daily gain. The data for the first 3 years, during which the molasses supplement was provided, were compared with those of the last 3 years, after the use of molasses was discontinued. The comparative results are presented in table 6.

At face value, the molasses supplement appears to have had little effect on animal production. The feeding of molasses increased carrying capacity 19.4 percent, but apparently it had an adverse effect on daily gain, the no-molasses treatment outgaining the molasses-fed treatment by 12.8 percent. The negative effect of molasses on daily gain implies that this essentially all-carbohydrate supplement exerted an adverse effect by widening the nutritive ratio of low-protein Napier grass forage. Since the supplemental feeding of molasses was accompanied by supplemental feeding of soybean oil meal, the net result should have been a slight narrowing of nutritive ratio.

The supplemental feeding of molasses had variable effects on treatments. The carrying capacity in the mature, short-grazing treatment showed practically no difference between molasses and no molasses, whereas the molasses supplement apparently increased the carrying capacity of the mature, long-grazing treatment by 40.9 percent. The large response to molasses in the latter treatment may possibly indicate that the presumably lower protein content of the Napier forage in this treatment was augmented by the protein in the soybean oil meal which accompanied the molasses supplement.

Daily gain in the immature, short-grazing treatment was not affected by molasses supplement, but in the other grazing treatments, improvement in daily gain was noted when the molasses supplement was discontinued.

TABLE 6. Effect of molasses and soybean meal supplement on carrying capacity and beef gains on Napier grass pasture, Haleakala Branch Station

GRAZING TREATMENT	CARRYING CAPACITY			DAILY GAIN POUNDS/ANIMAL/DAY			BEEF PRODUCTION POUNDS/ACRE/YEAR		
	With Supplement, 1942–1945	Without Supplement, 1945–1948	Percent Difference	With Supplement, 1942–1945	Without Supplement, 1945–1948	Percent Difference	With Supplement, 1942–1945	Without Supplement, 1945–1948	Percent Difference
Immature, short-grazing	334	302	10.7	0.93	0.91	2.2	339	276	22.8
Mature, short-grazing	381	365	4.2	0.88	1.07	—21.6	307	358	—16.6
Mature, long-grazing	523	371	40.9	1.02	1.20	—17.3	545	436	25.0
Mean	413	346	19.4	0.94	1.06	—12.8	397	357	11.2

[1] Molasses and soybean meal were creep fed daily in the first 3-year period. Approximate amounts fed each animal per day were molasses 2.39 pounds, and soybean meal 1 pound.

2. Soybean oil meal supplement

Soybean oil meal was given as protein supplement at the rate of 1 pound per animal per day during the first 10 grazings and was discontinued thereafter. Study of the TDN intake showed that 1 pound of soybean oil meal per day per animal having a median weight of 610 pounds accounted for 33.7 percent of the estimated intake of 1.12 pounds of digestible protein. Because of the high content of digestible protein of around 37.7 percent in soybean oil meal, the 1 pound of supplement provided one-third of the digestible protein requirements of the animals. Unfortunately, the effect of soybean oil meal supplement on animal production cannot be assessed because molasses was also given at the same time. However, a comparison of before-and-after data indicates that supplemental feeding of soybean oil meal had no marked effect on animal production.

Forage Production

Fresh Whole Forage Yield

The various green forage yield data are presented in table 7. Although yield and forage separation sampling techniques differed somewhat with treatments, on the whole, quite satisfactory results and information were obtained on the effect of treatments on forage production and characteristics. The difference in fresh whole forage yield between the immature and the mature grazing systems was clear-cut. The yields of the two mature systems were almost 2.5 times greater than that of the immature system. The fresh whole forage yield of 26.9 tons per acre per year in the immature system was considerably below expectation, even after due allowances were made for adverse climate and possible harmful effects resulting from grazing, such as soil compaction and injury to the crown by trampling. The mean regrowth recovery period of 109.0 days (15.6 weeks) was long enough to permit the plants to normally produce around 50 tons of green forage under the soilage system. Part of the low yield may have been due to the inherent depressive effect of grazing on forage production, such as soil compaction induced by grazing animals and disturbance in the plant food reserves through continued forage removal during the grazing period which averaged 17.35 days for this treatment. The disturbance in plant growth may have been further aggravated by the abnormal cycle of 4 drought years when the annual rainfall averaged 23 inches below the annual average of 76.75 inches. The treatments as a whole, however, showed practically no correlation between rainfall and forage yield.

In both of the mature systems, forage production was quite satisfactory, especially when due allowance was made for the drop in production with increase in elevation. Past results on fresh whole forage yields of Napier grass grown as a soilage crop under various elevations show conclusively that this grass is moderately sensitive to changes in elevation, yield decreasing progressively with increase in elevation. The relationship between elevation and fresh whole forage production was demonstrated dramatically in a test in which Napier grass strain 34:18 *(24)* was grown at three widely varying elevations that ranged from 300 to 3800 feet to measure the effect of elevation on forage production. The results are given in table 8.

In this test, forage production at the present site was one-half of that obtained at the 300-foot elevation. Part of the large difference in yield was due to differ-

TABLE 7. Total and leafy portions yields of fresh whole forage and component stem types of Napier grass, 6-year period, Haleakala Branch Station

SAMPLING TIME	TYPES OF STEM GROWTHS	PART OF CULM	GRAZING SYSTEM		
				Mature	
			Immature, short-grazing	Short-grazing	Long-grazing
			tons/acre/year	*tons/acre/year*	*tons/acre/year*
Before grazing	Total forage	Total	26.9	61.7	68.2
		Leafy portions	14.4	32.5	39.7
		Stemmy portions	12.5	29.2	28.5
	Primary stems Fallen-stem shoots Lala New crown shoots	Total Leafy portions Stemmy portions	No separations made of stem types as primary stems only were produced	No harvest made; above figures derived indirectly	No harvest made; above figures derived indirectly
After grazing	Total forage	Total	14.6	43.7	44.8
		Leafy portions	2.1	14.5	16.3
		Stemmy portions	12.5	29.2	28.5
	Primary stems	Total	13.4	Stems left intact; part of treatment	Stems left intact; part of treatment
		Leafy portions	No separation made		
		Stemmy portions			
	Fallen-stem shoots	Total	1.2	1.8	1.3
		Leafy portions	No separation made	0.9	1.0
		Stemmy portions		0.9	0.3
	Lala	Total	None produced due to the nature of treatment	26.1	26.7
		Leafy portions		7.2	8.5
		Stemmy portions		18.9	18.2
	New crown shoots	Total		15.7	16.8
		Leafy portions		6.3	6.8
		Stemmy portions		9.4	10.0
Calculated amount of forage ingested			12.3	18.0	23.4

TABLE 8. Effect of elevation on fresh whole forage yield of Napier grass strain 34:18

LOCATION ON ISLAND OF MAUI	ELEVATION ABOVE SEA LEVEL	FRESH WHOLE FORAGE YIELD	RELATIVE YIELD, PERCENT
	feet	*tons/acre/year*	
Haiku Field Station	300	126.7	100
Haleakala Branch Station	2160	61.6	49
Olinda Branch Station	3800	49.4	39

ences in soil, amount of incidence of clear skies, etc., but the major contributing factor was undoubtedly the various climatic elements that are associated with elevation.

According to the foregoing data, the present test was conducted at the upper limits of adaptability of Napier grass to elevation. The fresh whole forage yields of 61.7 and 68.2 tons recorded by the two mature treatments could be rated as outstanding inasmuch as the above yields were obtained from an area located at the upper limits of adaptability of Napier grass; and, in addition, the yields were obtained from pastures which were invariably lower in forage production as compared to production under the soilage system.

Napier grass grown as a soilage crop at relatively low elevations under irrigation and fertilization by dairies of Hawaii follow the annual march of length of day and associated temperature, but Napier grass pastures in the present experiment were little affected by length of day, temperature, or rainfall. Animal production was also scarcely affected by the vicissitudes in weather conditions.

The small difference in yield of 10.5 percent between the short- and long-grazing treatments of the mature system indicated that the difference in lengths of grazing periods of 17.89 and 42.80 days had little effect on forage production.

Although the whole forage yield of the immature, short-grazing treatment was low, there was little fluctuation in the year-to-year production so that the low yield cannot be attributed to progressive decrease in yield due to lack of persistence.

The fairly consistent forage and animal production in all treatments over the 6-year period shows that productivity and persistence of Napier grass under pasturage can be maintained under proper grazing management. Past failures of Napier grass pasturage that have been occasionally reported were probably due largely to faulty grazing practices and not to any inherent shortcomings in this grass as a pasture plant.

Both forage and animal production data show that Napier grass pasturage is among the highest in productivity. Part of its excellent performance is its ability to maintain relatively equable production even during spells of cold weather and drought. Younge and Ripperton *(32)* also reported that there were practically no differences in the number of grazings per year, and in dry matter yield and protein content in grazeable forage between wet and dry years, even though the annual rainfall varied from 33.1 to 82.9 inches.

Napier grass also has certain attributes not found in other tropical grasses. Because of its tall and thick but flexible stem growth, very little loss was incurred from trampling and soiling. In most tropical grasses, especially when the growth becomes lush through fertilization, losses from trampling are considerable because trampled forage becomes soiled readily and is not ingested by the animals. Losses from trampling in the present test were less than 5 percent.

The negligible loss from trampling in Napier grass was also perhaps greatly aided by the planting system used in this experiment. The 7-foot interrow spacing between paired rows effectively prevented the interlocking of robust plant growths in this tall-growing grass. Since the cattle were able to move about freely, losses from trampling were reduced to a minimum.

It was also noted that preferential grazing is nonexistent in Napier grass pasturage mainly because the animal droppings fall to the ground and do not soil the forage growth. Also, because of the lack of preferential grazing, recovery from grazing is very uniform. Freedom from weeds is yet another good characteristic of Napier grass.

Forage Segregation by Stem Types

Due to the nature of the treatments, the distribution pattern of stem types between immature and mature systems of grazing was sharply defined. The immature system was comprised entirely of young primary stems, whereas in the mature system they were completely lacking. In the mature system, in place of primary stems, three types of stems were produced as follows: lala, new crown shoots, and shoots produced from prostrate stems. The proportionate distribution of stem types in the short-grazing and long-grazing treatments of the mature grazing system was fairly close except for the fact that in the long-grazing treatment, the green whole forage yield of lala was double that of new crown shoots but in the short-grazing treatments, the yield of lala was 44 percent higher than that of the new crown shoots.

Although new crown shoots are produced the year around, their production increases markedly in the late spring months, from March through May. There is considerable decrease in crown-shoot production during the summer months when rainfall is at its lowest ebb, which pretty well nullifies the favorable growth factors of high temperature and long days.

As Napier grass is a short-day plant, flower heads are produced in considerable numbers between the months of November to March. However, no adverse effects of flowering were noted in either forage or animal production.

After-grazing harvests of the immature treatment showed that 4.6 percent of the primary stems had been trampled during grazing. Since the trampled stems were invariably soiled, they represent loss in forage production. In both of the sub-treatments in the mature system, the trampled stems usually struck root and new shoots were produced so that actual net loss from trampling was nil. The forage contribution from the new shoots produced from trampled stems was minor, representing 4.9 and 2.4 percent of the total forage production in the short-grazing and long-grazing treatments, respectively. The various forage segregation data are presented in table 9.

Leaf and Stem Segregations

All types of stem growth harvested before and after grazing were segregated into leafy and stemmy portions for the determination of percent leafiness and yield of leafy portions. The percentage of leafy portions was relatively uniform irrespec-

TABLE 9. Percent contribution of various stem types to before-grazing whole forage and leafy portions yields, and percent of leafy portions in various stem types of Napier grass, 6-year average, Halealaka Branch Station

COMPARISONS	TYPE OF STEMS	IMMATURE	MATURE	
			Short-Grazing	Long-Grazing
		percent	*percent*	*percent*
Percent contribution to whole forage yield	Primary stems	95.4	0	0
	Lala	0	56.2	65.9
	New crown shoots	0	38.9	31.7
	Fallen-stem shoots	4.6	4.9	2.4
Percent contribution to leafy portions yield	Primary stems	100.0	0	0
	Lala	0	53.1	60.2
	New crown shoots	0	41.1	35.8
	Fallen-stem shoots	0	5.8	4.0
Percent leafy portions in various stem types	Primary stems	53.3	0	0
	Lala	0	50.2	53.2
	New crown shoots	0	55.6	65.7
	Fallen-stem shoots	0	60.0	66.7
	Combined stem types	53.3	52.8	58.2

tive of treatment or stem type. There was a semblance of a linear increase in percent leafiness in the following order of ascendency: lala, new crown shoots, and shoots produced from trampled stems. The differences, however, were not significant.

The percent leafy portions in the combined stem types of the treatments ranged from 53.5 to 58.2; this is exceptionally high for Napier grass. As a soilage crop harvested at 10–15 weeks of age, the percent leafy portions in Napier grass is seldom over 40 pecrent. On a comparative basis of yield of leafy portions, the yields of the two mature treatments compare favorably with yields obtained under the soilage system. The mean total yields of leafy portions per acre per year for the mature, short-grazing and mature, long-grazing treatments, were 32.5 and 39.7 tons, respectively. By way of comparison with yield under the soilage system, a good total whole fresh forage yield of 100 tons of Napier grass with 40 percent of leafy portions will have a yield of 40 tons of leafy portions. An almost comparable yield of leafy portions was obtained from a materially lower whole forage yield of 68.2 tons from the mature, long-grazing treatment, under what is generally considered marginal climatic zone for Napier grass.

Utilization of Forage

The high productive capacity of tropical grasses obtained under the soilage system can seldom be capitalized upon when the grasses are grown for pasturage. Thus, as pasturage, Dallis grass is generally equal to Napier grass although the latter outyields the former easily by 2 to 1 as soilage. One of the biggest problems confronting graziers in the tropics is the low degree of utilization of rank-growing tropical grasses, among which Napier grass has been regarded as the chief offender.

The data on degree of utilization presented in table 10 are quite illuminating. The degree of utilization was highest in the immature system, which was at 45.56 percent, and the difference between this treatment and the two mature systems was

TABLE 10. Degree of utilization of Napier grass forage by animals in three systems of grazing, 6-year average, Haleakala Branch Station

	IMMATURE	MATURE	
		Short-Grazing	Long-Grazing
	tons/acre/year	*tons/acre/year*	*tons/acre/year*
Before-grazing yield of leafy portions	14.4	32.6	39.7
After-grazing yield of leafy portions	2.1	14.6	16.3
Amount of leafy portions grazed off	12.3	18.0	23.4
Percent of leafy portions grazed off	85.4%	55.2%	58.9%
Percent of total production grazed off	45.6%	29.2%	34.3%

found to be significant. The degree of utilization in the mature, short-grazing treatment was 29.2 percent and in the mature, long-grazing treatment, 34.3 percent, both of which are creditable degrees of utilization. The high degree of utilization in the immature treatment was highly instrumental in overcoming the large difference in total forage production between this treatment and the two mature systems.

The high degree of utilization in the immature treatment was due to the high degree of intake of leafy portions. In the immature system, 85.4 percent of the grazeable forage was ingested as compared to 55.2 percent in the mature, short-grazing treatment and 58.9 percent in the mature, long-grazing treatment.

The high degree of utilization of forage in the immature treatment apparently did not exert any cumulative, successive, or depressive effect on yield, as the annual yields, though mediocre, were fairly stable over the duration of the trial. The immature treatment probably resulted in the production of better quality forage—high palatability, accessibility of forage, and, possibly, better balance in feeding value of the leafy portions.

In the final analysis, however, the mature, long-grazing treatment produced the best animal gains principally as a result of materially higher yield of leafy portions which more than made up for the lower precentage of utilization.

TDN Intake from Ingested Forages

As most of the measurements made on forage production were approximations, it is of interest to ascertain how close they came to true figures as reflected in animal production. The amount of forage ingested, for example, was derived by subtracting the after-grazing yields from the before-grazing yields. Data on various TDN calculations are presented in table 11. The estimated TDN supplied annually by ingested forage and supplementary feeds shows that its supply was more than adequate to account for the calculated intake of TDN by the animals in the grazing treatments. The apparent excess supply of TDN in the estimated amount of forage ingested was 13.5 percent for the immature, short-grazing treatment; 31.6 percent for the mature, short-grazing treatment; and 33.2 percent for the mature, long-grazing treatment. In the first of these treatments, the intake and available supply are reasonably well balanced. In the two mature treatments, there

TABLE 11. TDN content in ingested forage and supplementary feeds and TDN intake of animals by treatments of Napier grass pasture, Haleakala Branch Station

TREATMENT	Total Fresh Forage Yield: Before Grazing	Total Fresh Forage Yield: After Grazing	Total Fresh Forage Yield: Difference, Amount Grazed	Carrying Capacity	Total TDN* Intake of Animals	TDN Content of Estimated Amount of Forage Grazed	TDN Contribution by Supple-mental feeds	Estimated Total TDN at disposal of Animals	Estimated % Wastage TDN at disposal of Animals
	tons/acre/year	*tons/acre/year*	*tons/acre/year*	*cow/days*	*pounds/acre/year*	*pounds/acre/year*	*pounds/acre/year*	*pounds/acre/year*	
Immature, short-grazing	26.9	14.4	12.5	318	2926	3075	247	3322	13.5
Mature, short-grazing	61.7	43.7	18.0	356	3275	4500	288	4788	31.6
Mature, long-grazing	68.2	44.8	23.4	447	4112	5850	306	6156	33.2

* TDN (total digestible nutrients) intake per animal per day at 9.2 pounds for 610-pound animal; the TDN content of grazeable forage was estimated at 12.5 percent.

were sizeable apparent wastes of available supply of TDN. As in many other measurements taken, the difference in apparent utilization of available TDN between the immature and the two mature treatments was sharply demarcated. The close agreement between availability and intake in the immature treatment indicates that fullest utilization of available TDN was due to adequate quality of forage and supplemental feeds supplied to the animals in this treatment. Since the quality of feed ingested in this treatment more nearly met Morrison's *(18)* standard, this treatment was able to support animals to the limit of its productive capacity. The above result is still another indication of the production of superior quality forage by the immature treatment.

The apparent large waste of available TDN in the two mature treatments may be due to low forage quality or to errors in the estimates in the yield of grazeable forage, or both. Analysis of the protein content shows that the forage from the mature systems is slightly lower in protein than is that of the immature system. There was also no doubt that errors in yield determinations were considerably higher for the mature systems than for the immature system, inasmuch as yield determinations in the former treatments were made from partial harvests by hand, which are subject to personal bias, while harvests of the immature system were obtained more accurately through machine harvesting.

In spite of the materially greater efficiency in the utilization of grazeable forage in the immature treatment, the end results were in favor of the two mature systems, particularly the mature, long-grazing treatment, because the higher forage production more than compensated for the lower forage quality and utilization.

From the standpoint of production of quality forage, as reflected largely in the high degree of utilization of grazeable forage, the immature treatment was superior to either of the mature systems. The quality forage produced in the former treatment, however, was chiefly the result of artificial manipulations; namely, the mowing back of stubble after grazing was completed so that new succulent growth could be regenerated anew after each grazing and the grazing of the new young regrowths while they were still in the immature stage of growth. The high cost of producing good quality immature forage was not compensated for by adequate yield in forage or animal products. As a ranch practice, the immature system of grazing is not justified because it is too costly to operate.

Of the three systems of grazing studied, the mature, long-grazing treatment is the easiest and cheapest to operate; and, in addition, it results in the production of the largest amount of grazeable forage and animal products.

The superiority of the mature, long-grazing treatment probably can be further enhanced by improving its forage quality to a point where nearly all of the grazeable forage will be ingested, which will result in an additional increase in animal production. The forage quality can be improved considerably either by supplemental feeding of high-protein concentrates, or by elevating the protein content of the grazeable forage by adequate fertilization, from the present low level of 7.17 percent and the nutritive ratio of 1:13.3 to the desired levels of 12.53 percent protein and the nutritive ratio of 1:7.2, as called for in Morrison's *(18)* standard. Adequate fertilization will not only increase the protein content to the desired level, but, in addition, the forage production will also increase. The elimination of 33.2 percent wastage in the ingested forage alone will theoretically increase animal production in a like amount. In addition to the elimination of wastage of ingested forage, the adequacy of protein in the grazeable forage is likely to result in an increase in the percentage utilization of available grazeable forage, which presently is 58.94 percent. An increase in the production of grazeable forage may be expected from adequate fertilization. Proper fertilization may result in as much as a twofold increase in animal production.

Chemical Composition

Although only a fraction of the yield harvests and forage separations were analyzed for dry matter and protein, still the number of analyses was large enough and covered enough representative types of samples so that a fairly clear picture was obtained on the chemical composition of forages produced from all grazing treatments. The more pertinent chemical analyses are presented in table 12. The outstanding feature of the dry matter and protein analyses is the relatively small differences between treatments. The range in both dry matter and protein contents was also small, indicating that, contrary to expectations, the frequent dry spells had relatively little effect on the chemical composition. Younge and Ripperton *(32)* also noted negligible influence of drought on protein content. The small differences between treatments were not significant. The protein contents of whole forage were about equal to those obtained from Napier grass grown for soilage purposes at the central Hawaii Agricultural Experiment Station in Honolulu, Oahu. The protein contents of the leafy portions were about one-half of the high-protein-analysis forage so that the nutritive ratio was considerably wider than the ratio called for in Morrison's standard *(18)*. The wide nutritive ratios of 1:13.1, 1:16.7, and 1:13.3 in the leafy portions of the immature and mature, short-grazing treatments; and the mature, long-grazing treatment, respectively, are almost double the nutritive ratio of 1:7.2 suggested by Morrison for animals averaging 610 pounds.

The wide nutritive ratio of ingested forage without adequate protein supplement was probably the chief causative factor for the apparent low utilization of available TDN in the mature treatments. For the mature, short-grazing treatment, the protein content of 6.17 percent on an oven-dry basis in the leafy portions must be increased to 12.53 percent, or roughly doubled, by proper fertilization to obtain the favorable nutritive ratio of 1:7.2. The other alternative is to augment the deficit in protein by supplemental feeding of protein concentrate. The intake of 9.2 pounds of TDN from forage with 6.17 percent protein content on an oven-dry basis will provide 0.715 pound of the 1.12 pounds of the required digestible protein. The deficit of 0.405 pound of digestible protein can be made up by supplemental feeding of approximately 1.10 pounds of soybean meal per day per animal weighing 610 pounds.

Of the two alternatives for providing adequate protein in the ingested forage, adequate fertilization to increase the protein content in the forage may be the more desirable. Chances are, with increased fertilization, forage production will also increase so that in addition to the complete utilization of approximately 33.2 percent of the grazeable forage presently "wasted," which in itself would increase animal production by 33.2 percent, the additional increase in the production of quality forage will result in further increase in animal production perhaps up to 30 percent or more, depending upon the amount of fertilizer used and crop response to added fertilization.

In a frequency-of-cutting test with Napier grass *(23)* conducted at the Hale-

TABLE 12. Comparison of dry matter and protein contents of Napier grass forage in Haleakala Branch Station test with those of other workers

Source of Data	Description of Forage	Percent Dry Matter	Percent Protein on Oven-Dry Basis	Percent* Digestible Protein	Percent Total Digestible Nutrient	Nutritive Ratio	Number of Analyses
	Whole forage, mature (*9*)†	21.1	4.88	2.61	12.5	22.0	30
	Whole forage, mature (*31*)	23.8	5.04	2.52	12.2	21.1	1
Other	Whole forage, past mature (*31*)	35.6	4.49	2.81	23.8	20.4	1
Workers	Whole forage, 12-week-old (*23*)	15.4	11.69	6.14	–	8.8	17
	Grazeable forage, check (*32*)	–	7.17	3.94	–	–	–
	Grazeable forage, check (*32*)	–	9.67	5.32	–	–	–
	280 pounds nitrogen per acre per year	–	9.83	5.41	–	–	–
	Whole, immature, short-grazing	19.79	4.90	2.70	–	22.4	10
	Whole, mature, short-grazing	23.58	4.83	2.66	–	18.9	5
Present	Whole, mature, long-grazing	24.61	4.78	2.63	–	21.8	4
Experiment	Leafy portions, immature, short-grazing	21.02	7.65	4.21	–	13.1	6
	Leafy portions, mature, short-grazing	21.09	6.17	3.39	–	16.7	5
	Leafy portions, mature, long-grazing	23.94	7.51	4.13	–	13.3	5

* Figures calculated from assumed percent digestibility of protein at 55.
† Literature citation.

akala Branch Station in 1941–1945, high forage and protein yields were obtained from all four cutting treatments harvested at regular intervals of 9, 12, 15, and 18 weeks and liberally fertilized with ammonium sulfate at the rate of 2000 pounds (400 pounds of nitrogen) per acre per year. In the treatment cut every 15 weeks, which is equivalent to the mean growth recovery period in the immature treatment, the following results were obtained: (1) green whole forage yield—79.92 tons per acre per year, (2) percent protein in forage on oven-dry basis—9.95 percent, and (3) protein yield—2,720 pounds per acre per year. Incidentally, the exceptionally high protein yield in this treatment compares favorably with protein yields from alfalfa, koa haole (*Leucaena leucocephala*) (24), and desmodiums, three of the ranking soilage legumes of the tropics. In comparison with the above-cited performance of Napier grass in the frequency-of-cutting experiment, the fresh whole forage yield of the immature treatment in the present test was about one-third, at 26.9 tons, and the protein yield was about one-sixth, at 433 pounds.

The low protein content in the forage in all treatments was probably due to inadequate fertilization, especially of nitrogen fertilizer. The annual application of 72 pounds of nitrogen per acre (from 1 application of 150 pounds of 8–12½–6 "B" fertilizer plus 2 applications of 150 pounds each of ammonium sulfate) per year is a high rate of application by ranchers' standards, but apparently the amount was not high enough to bring up the protein content of the leafy portions to the desired level. Even in the immature treatment, the amount of nitrogen applied was only sufficient to account for the protein contained in the leafy portions only. Under adequate nitrogen fertilization, the protein content of leafy portions on an oven-dry basis ranges from 10 to 15 percent with an average of around 12 percent. Raising the present protein content of 7.65 percent in the leafy portion in the immature treatment, to the adequate level of around 12½ percent, might call for doubling and even tripling in the rate of nitrogen fertilization. The inadequacy of nitrogen fertilization was evident in forage growth as indicated by a yellowish tint in the foliage and by spindly stem growth. An alternative to additional fertilization would be either supplemental feeding of high-protein concentrates or incorporation of legumes in the pasture. The latter procedure merits investigation.

SUMMARY AND CONCLUSION

Three systems of grazing management of Napier grass pasture over a 6-year period were investigated at the Haleakala Branch Station, Maui, lying at 2160 feet, near the upper elevation (lower temperature limit) for the economic growth of Napier grass. Systems utilized were (1) grazing at the immature stage of growth for a short duration, (2) grazing at the mature stage of growth also for a short duration, and (3) grazing at the mature stage of growth, but at half the stocking rate so that the duration of grazing will be about twice as long. Two-node stem cuttings of Napier grass strain 34:33 were planted in paired rows spaced 3 feet between rows and 7 feet between two paired rows. All treatments were fertilized after each grazing as follows: "B" fertilizer (8–12½–6) was given once a year to the spring grazing at the rate of 150 pounds per acre, and ammonium sulfate, also at the rate of 150 pounds per acre, was given to each of the approximately two grazings for the remainder of the year. During the first 3 years, grade Hereford steers were used; Holstein heifers were used for the last 3 years. During the first 11 grazings, supplemental feeds—soybean oil meal at the rate of 1 pound per animal per day and sugar cane molasses at an approximate rate of 2 pounds per animal per day—were given. Free access to bone meal and salt was provided throughout the duration of the experiment.

Two-pronged studies were conducted: (1) animal production; and (2) forage production, which included yield and forage quality studies. Trends were noted in carrying capacity and daily gains, but the differences between treatments were not significant. Comparisons on the basis of beef production showed that the mature, long-grazing treatment is significantly better than either of the other two treatments.

In the yield of fresh whole forage, both of the mature treatments outyielded the immature treatment by almost 2½ times. Likewise, the yield of grazeable forage of the immature treatment was significantly lower than that of either of the mature treatments, but the difference was considerably narrower. Forage segregation studies on stem types and percent leafiness showed trends, but none were significant except in the difference in percent utilization. The percent utilization of whole forage at 45.6 percent in the immature treatment was exceptionally high, and appears to be on a par in percent utilization with the best of meadow grasses of temperate regions. The immature treatment did induce the production of medium quality forage, but the superiority in quality forage production was more than counterbalanced by the materially higher, and all-around higher, forage production in the mature treatments. Furthermore, the grazing management technique used to maintain Napier grass pasturage in the immature stage for quality feed production is too artificial and costly for practical use.

The mature, long-grazing treatment produced the best results in most of the measurement criteria—carrying capacity, daily gain, beef gain, yield of grazeable forage, and forage ingested. In addition, this treatment comes closest to ranch management practices and is the most economical treatment for animal manipulations.

The sustained productivity of animals and forage over the 6-year period of the trial shows conclusively that both productivity and persistence of Napier grass pasturage can be maintained on an equal footing with the soilage system, at least for the three grazing management systems studied. Past failures of Napier grass pastures were most probably due to mismanagement in grazing and not to inherent weaknesses of Napier grass under grazing.

This experiment has not only proved that the productivity and persistence of Napier grass under pasturage can be maintained, but perhaps has with even greater import disclosed many admirable features of Napier grass pastures, features which are generally absent in other tropical grasses. Some of the characteristics that appear to be unique in Napier grass are: (1) ability to yield leafy portions on a par with the soilage system in a climatically marginal area, (2) stability in animal and forage production through widely fluctuating climatic conditions, (3) minimal forage losses from trampling and soiling, (4) freedom from preferential grazing and from weeds, and (5) high animal production that is fully the equal to that of ranking pasture grasses.

This study has shown that the growth of this semiwild and rankest growing of all forage grasses can be effectively harnessed by proper grazing management and thus can be made one of the top-ranking pasture grasses of the tropics, particularly under trying conditions of high elevation and widely fluctuating cold and dry spells. At least for climatically marginal lands, it appears to be the king of all pasture species. Better fertilization and greater refinement of grazing management will undoubtedly further enhance its value as a forage grass.

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